



# Malthusianism of the 21st century

Borja Montano<sup>\*</sup>, Marcos García-López

Universidad de Alicante, Ap. de correos, 99, 03080, Alicante, Spain

## ARTICLE INFO

### Keywords:

Population growth  
Population  
Economic growth

## ABSTRACT

This paper has arisen from a reflection of the current reality in terms of the postulations about what is known as the Malthusian economy. Since the Industrial Revolution to the present day, despite there having been a high increase in world population, technology has played a fundamental role in the increase in the level of wealth per capita. However, the continued growth of the population and the future forecasts indicate that technology with have the responsibility of continually being the key piece of economic growth. This paper seeks to analyse the future scenarios in order to better understand the conditioning factors of the sustainability of our population growth. If technology were not able to maintain production growth rates higher than the population growth rates, we would return to the scenario described by Malthus.

## 1. Introduction

In the classroom, it is common to explain that Malthusian theory was no longer applicable after the Industrial Revolution due to technological progress (Malthus, 1823b). Nowadays, there are those who consider that everything is underpinned by a series of limited resources, therefore, limitless growth is not possible in a world with limited resources. If technology were not able to maintain production growth rates higher than the population growth rates, we would return to the scenario described by Malthus, which would give rise to three possibilities or a combination of them:

- A situation may arise whereby, although the population growth is higher than production growth on a global scale, a polarisation be-

tween the most developed world and the rest of the world is generated. It may also be the case that, although the global GDP per capita diminishes,<sup>1</sup> the GDP per capita of the developed world increases, which would also increase global inequality.

- The second possibility would be a catastrophe which would radically reduce the world population, what has happened on many occasions throughout history and is, in fact, what Malthus maintained in his theory. This catastrophe could take the form of a natural disaster, a war, an epidemic or the consequence of an exhaustion or an unpredicted extreme scarcity of an essential resource.
- The third possibility would be where, faced with a scenario which we have described in which wealth grows at a slower rate than the population, a birth control policy is implemented in those areas of the planet where demographic growth is concentrated.<sup>2</sup>

The three  
possible future  
scenarios



- 1) Polarisation between rich and poor regions.
- 2) A catastrophe radically reduces the world's population.
- 3) Effective population control policies are implemented.

<sup>\*</sup> Corresponding author.

E-mail addresses: [Borja.montano@ua.es](mailto:Borja.montano@ua.es) (B. Montano), [marcos.garcialopez@ua.es](mailto:marcos.garcialopez@ua.es) (M. García-López).

<sup>1</sup> It is important to indicate that a reduction in global GDP per capita does not imply a reduction in GDP, rather, the rate of population growth is higher than that of GDP leading to a lower GDP per capita which is calculated by dividing the GDP by the population.

<sup>2</sup> It is worth pointing out that, although on a global level we have continuous growth, there are regions of the planet that no longer experience demographic growth and those that do.

It should be remembered that the three aforementioned scenarios are based on the idea that technology is not able to palliate the effects of population growth. This paper forms part of a line of research that seeks to study the effects of population growth and the changes in consumption patterns on the sustainability of the planet. These aspects are relevant in order to reach sustainability, what justifies our final objective of analyse the real cause of the problems related with the evolution of the population and consumer patterns and in future studies we will analyse the consequences of this for:

- Energy costs and the tensions in this market.
- The food market, the quality of food, the consumption of resources necessary for their production.
- The availability of water and the costs of generating it.

Furthermore, there are certain correlations between the above-described elements that give cause for concern. If, for example, we analyse the link between water and energy, we can see that a higher consumption of water increases the amount of energy needed to obtain it, desalination is the most evident proof of this. Therefore, the problem with this technology is that it increases the energy and economic cost of obtaining water in comparison of other alternatives, reason why desalinated water is a solid alternative to generate an increase in available water resources only when all other sources have been exhausted.

Recent work still shows the existence of the income-GDP link (Brueckner and Schwandt, 2015), so this research is of great importance in order to carry out an analysis of the demographic evolution and its consequences on the pressure on resources and sustainability. However, as an economy evolves, the determinants of its demographic evolution become more diverse and complex. Specifically, these determinants can be grouped into demographic factors, socioeconomic conditions, natural amenities, accessibility to transport and development land use (Alvaréz-Díaz et al., 2018). Among the above factors, technological progress is one of the most related to sustainability to the extent that it improves efficiency and, therefore, saves scarce resources, however, it is also complexly related to population growth. This relationship has a double meaning, firstly, greater technological progress is related to an increase in the population, but, secondly, a larger population leads to a reduction in productivity in the field of research (Coccia, 2014). Finally, it should be noted that territorial factors are an important determinant of population evolution. In Spain, the heterogeneity of the different regions that form it has significantly conditioned the distribution of the population (Gutiérrez-Posada et al., 2017). This is of great relevance for the analyses, as it justifies that the measures aimed at achieving sustainability must be a combination of large-scale and regional-scale measures.

The question that this study wishes to answer is what factors will determine the evolution of the world population in the future. For which we will analyse the behaviour of the population throughout history. Our initial hypothesis is that there are two types of dynamics, that of the countries before their demographic transition and that of countries which have already experienced this transition. The countries which have not experienced their demographic transition have high income-demographic growth elasticity and they are less developed nations. On the other hand, in developed countries the determinants of demographic evolution have changed and the income-demographic growth elasticity is low.

Contrasting this hypothesis is necessary to estimate the demographic growth in the next years since we need to determine where in the demographic transition they are located to carry out the future research. This allows us to predict the future demographic growth, which will not be infinite, although it will generate pressure on the resources which could be compensated with technical and technological progress, which increases efficiency. The problem of this is our dependency on the technical progress to palliate the collateral effects of the increase in the population. For that reason, this article is the basis of an essential

investigation that will provide valuable information to take measures towards sustainability.

## 2. Malthusian theory

In the first chapter of the first book on the obstacles faced by population growth, Malthus<sup>3</sup> explained that, when presented with the possibility of seeing our children without the necessary resources to be raised adequately, human beings may take the decision to limit the size of our families<sup>4</sup> (Malthus, 1823b, 1830). But we may also be carried away by our instinct and decide to have more children and try to bring them up (Malthus, 1846). One of the most well-known phrases of Malthus says that the population grows by geometric progression while food grows by arithmetic progression. It is interesting to see the geographical location of demographic growth in recent years. Graph 1 shows the distribution of the population throughout the world in 1975 and graph 2 in 2025.

These graphs enable us to affirm that there is not a homogeneous distribution of either humans on the planet or the growth rate. In his initial work (Malthus, 1846)<sup>5</sup> Malthus said that the population doubles every twenty-five years when there are no obstacles to its growth. In this way, there is a geometric growth between periods. However, today we know that this affirmation that quantifies the growth of the population was coherent at the time when it was written but it became untenable in the past after it was written and for the future. The total population in 2017 was 7,722,727,000 people. In 1990, that is, twenty-seven years earlier, there was a world population of 5,263,593,000. The population growth in the period 1950–2000 was approximately 141% (a cumulative annual rate of 1.78%), while in the period between 1900 and 1950 it grew by 53% (cumulative annual rate of 0.85%). This means that Malthus' predicted growth rate whereby the population would double every twenty-five years has not been fulfilled. However, the data also indicates that demographic growth is being very aggressive (information obtained from the databases: Census Bureau, International Data Base<sup>6</sup> and USA Trade Online<sup>7</sup>). Malthus also predicted that resources would increase in arithmetic progression. However, in recent years, technology has enabled the GDP per capita to grow continuously even though the population has also grown. Therefore, in practice, Malthus' theory loses its validity during the period between the industrial revolution and the present day. In Graph 3, based on the database of Angus Maddison, we have calculated the total world population and the GDP per capita and we can see that despite the continued increase in the population level there has also been a continued increase in the level of wealth per person.<sup>8</sup>

In order to demonstrate that the population has the capacity to double every 25 years, Malthus referred to the population growth in the United States during the eighteenth century, where, thanks to early marriages and an abundance of food resources, there were no restrictions to the natural force of expansion of the population (Malthus, 1798, 1803). This interests us to the extent that we wish to know about the original theory

<sup>3</sup> The first of Malthus' publications dates back to 1798 and, according to the author himself, was based on a hand-written text by M. Godwin and also on authors such as Adam Smith (Malthus, 1800).

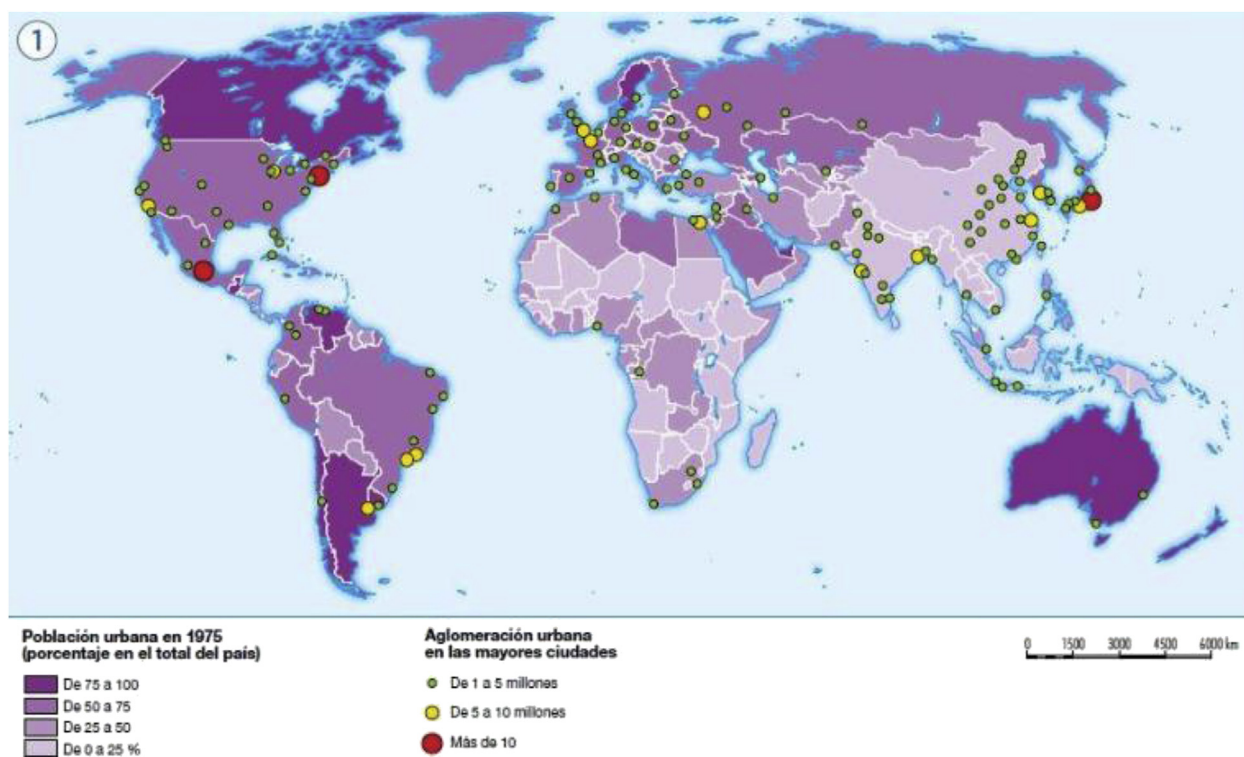
<sup>4</sup> This affirmation leads us to a situation in which the scarcity of resources is inevitable unless demographic growth which, according to Malthusian theory, would occur not voluntarily but as a result of an increase in mortality due to the scarcity of resources which would give rise to war, famine.

<sup>5</sup> It is worth pointing out that we are quoting the translation into Spanish which is why the year of publication is different.

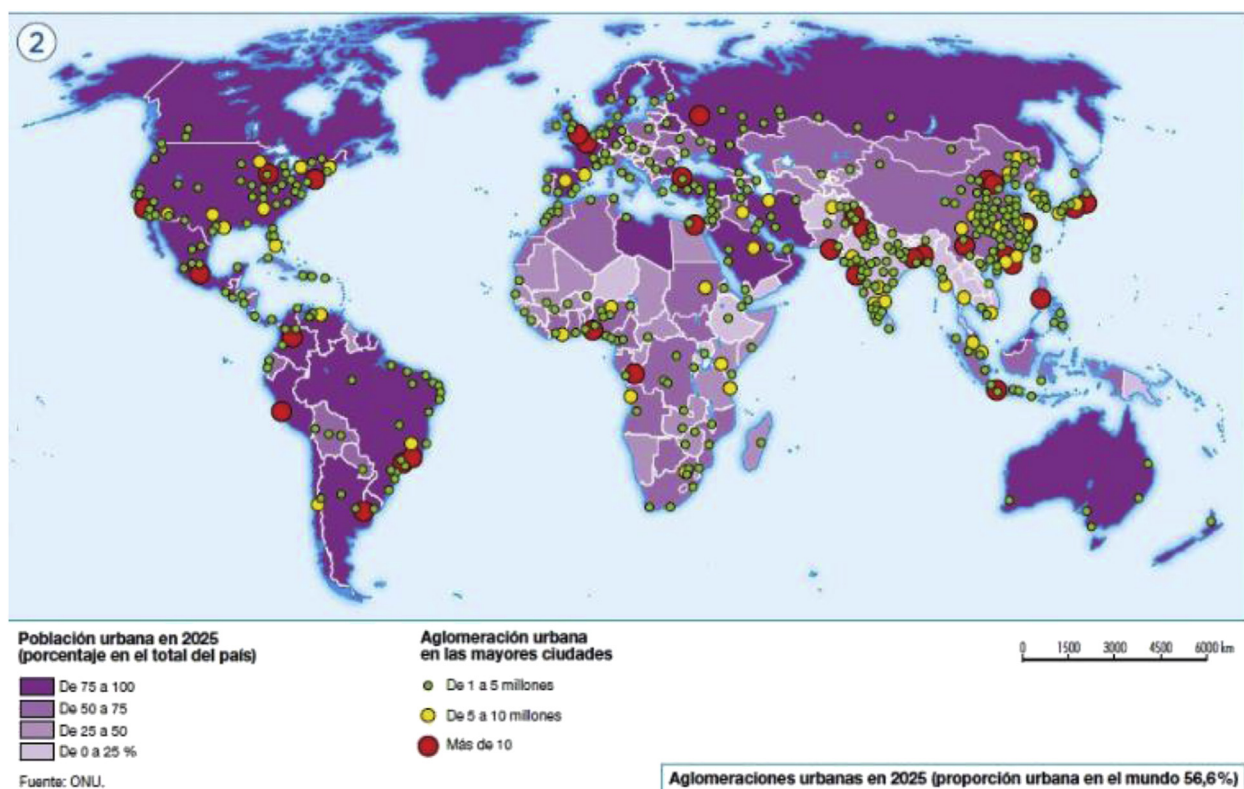
<sup>6</sup> Demographic data.

<sup>7</sup> Trade data.

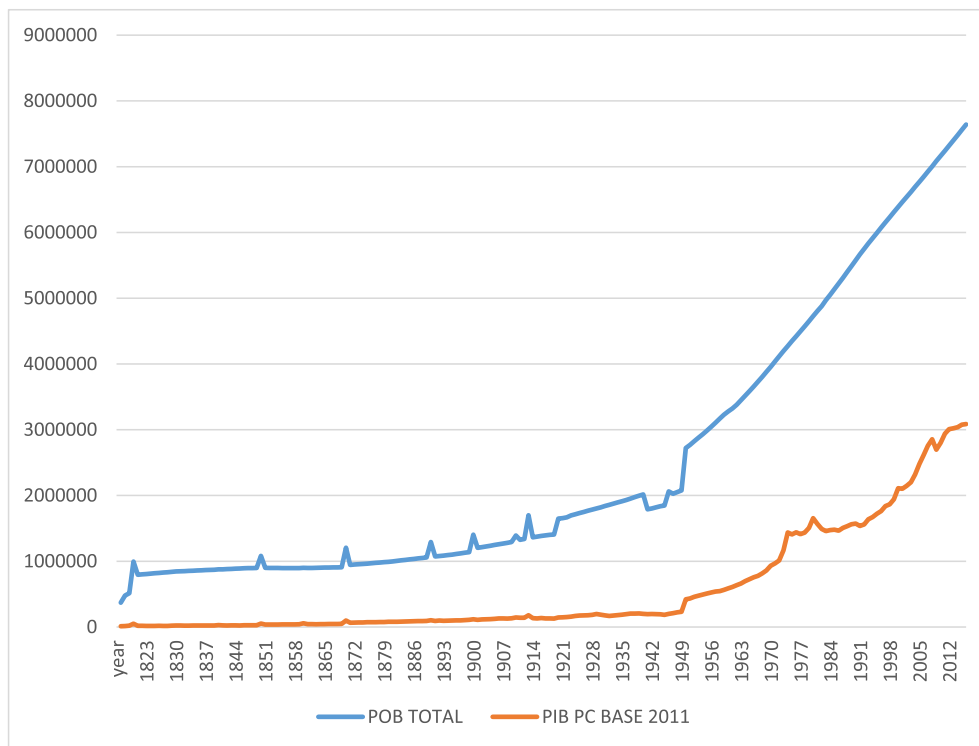
<sup>8</sup> It is important to note that we have obtained world GDP per capita by dividing total GDP by the number of inhabitants on the planet. However, it must be noted that there is great inequality in the world. Therefore, it should not be assumed that on average people have the calculated GDP per capita, rather, the large majority have much less wealth than a minority which has many more resources.



**Graph 1.** World population in 1975  
Source: UN (2012).



**Graph 2.** shows the estimated distribution of the population in 2025.  
Source: UN (2012).



**Graph 3.** evolution of the population<sup>9</sup> and the GDP per capita<sup>10</sup>

Source: Own elaboration based on the data of Angus Maddison.

of Malthus but not in order to reassess some of its aspects in the current world as we have shown that the population does not double every 25 years as a general rule. But this is something that is more related to whether there has been a demographic transition or not.<sup>11</sup>

One aspect that should be highlighted is that after wars or epidemics with very high death rates in a specific region, the population that survives has a relative abundance of food resources. If we observe [Graph 3](#) again, we can see that after the First World War and particularly after the Second World War, the global population grew at a higher rate than before. The growth capacity of the surviving population in favourable conditions meant that the original population was recovered in a short period of time.<sup>12</sup>

On the other hand, there are what Malthus calls obstacles and checks to population growth ([Malthus, 1846](#)). Malthus distinguishes between privative and destructive obstacles. As we have seen, privative checks are voluntary. One type of privative check is the moral restriction such as abstaining from marriage, chastity or, as in more recent times, the postponement of marriage until sufficient resources have been accumulated.<sup>13</sup> According to Malthus, the second type of privative checks are vices such as licentiousness, unnatural practices, the violation of the marital bed, criminal and irregular unions ([Malthus, 1846](#)). An

adaptation to the current ideology would be that all decisions taken so as to avoid having children are privative checks.

On the other hand are the destructive obstacles which, as previously mentioned, are not voluntary. First, there is destitution such as poorly paid or dangerous occupations, poverty, poor nutrition and/or hunger, unhealthiness, diseases. The other type of destructive checks are misfortunes such as wars, natural disasters or political conflicts.

In short, the fundamental proposition of the content of Malthus' book is based on three premises. First, the means of subsistence limit the population. Second, an increase of these means of subsistence leads to an increase in the population and finally, as a consequence of the first two premises, population growth cannot be checked unless a situation of destitution arises.

Malthus has been a highly influential author in economic thought [see ([Malthus, 1815a, 1815b, 1820, 1823a](#)))] which is why this study, seeking to analyse the consequences of population growth, should be based on the foundations laid by him. Malthus was highly influential in economic, political, social and scientific thought. The author Harriet Martineau presented concepts and explanations about production, distribution, the consumption of wealth and behaviour; we can observe that her work is highly influenced by Malthus' studies ([Martineau, 1832](#)). The work of the evolutionary biologists Charles Darwin and Alfred Russel Wallace was influenced by Malthus with respect to the idea of natural selection and the theory of evolution. Darwin realised that the Malthusian catastrophe applied to what Candolle called "Nature's war" between plants and animals, which caused the size of a population to remain stable ([Candolle, 1813](#)). Similarly to Malthus' theory in the case of humans, animals always reproduced in larger quantities than the available resources. In his autobiography, Alfred Russel Wallace wrote that the idea of natural selection occurred to him when he was in bed with a fever and he thought about the positive checks described by Malthus and their effect on human population growth. Wallace claimed that these same causes were continually acting in the case of animals and given that

<sup>9</sup> Expressed in thousands of inhabitants.

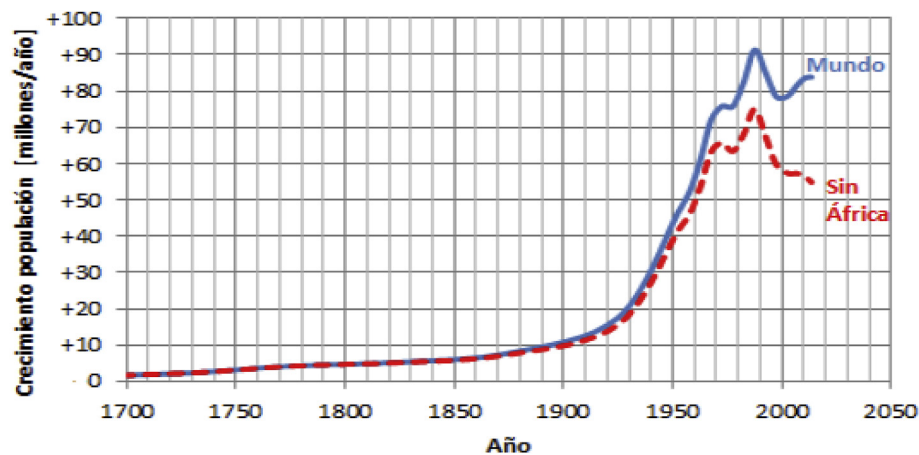
<sup>10</sup> Expressed in constant prices in 2011 dollars.

<sup>11</sup> Countries that still have a low level of development may go through a phase with demographic growth rates similar to those described by Malthus, but today we know that this is more characteristic of a specific moment experienced by a country and not a general norm.

<sup>12</sup> It should be noted that as well as the afore-mentioned demographic transition, it may have be the case that after a period such as the two world wars, the rhythm of demographic growth accelerates.

<sup>13</sup> Today, in many European countries, some of these privative checks form part of our moral and culture.





**Graph 4.** Evolution of the population over the last few centuries.<sup>20</sup>  
Source: UN (2012).

they reproduced more quickly than humans, the destruction that these checks caused each year had to be enormous to limit the number of each species. In 1864, Wallace published the article “The Origin of Human Races and the Antiquity of Man Deduced from the Theory of “Natural Selection”. In this article and others of Wallace’s studies we can see the direct influence of Malthus’ ideas. Keynes claimed that a geometric proportion can counterbalance another and in this way, in the nineteenth century, the problem of population growth was laid to rest because the growth in wealth compensated it, however, in some way, the problems could reappear because the pressures on certain resources had returned (Keynes, 1920). It is worth mentioning the book “The population bomb<sup>14</sup>” by Paul R. Ehrlich. It constituted a reference text for the ecology movement in the 1960s and has provided arguments in favour of research in contraceptive methods. Ehrlich observed that in the 1930s, the global population had doubled in just one generation, growing from two to four billion people and that resources, including food, have certain limits (Ehrlich, 1968). The critics of Ehrlich’s work argued that the study is a mere repetition of Malthus’ study but that, at least Malthus had not made a firm prediction of a imminent catastrophe while Ehrlich warned of a large-scale disaster in the two subsequent decades.

Malthusian theory has not expired and still makes sense due to technical progress, as resources such as energy are subject to the enormous pressure derived from the need to show growth rates in the production of the resource that exceed those of its demand, which leads to the elaboration of new measures in search of saving energy (IDAE Instituto para la Diversificación y Ahorro de la Energía, 2010; IDAE, 2011). This same need applies to food and water resources.

The Club of Rome commissioned the MIT to write the report “The limits of growth<sup>15</sup>” which was published in 1972 before the first oil crisis (Meadows, 1972). A team of seventeen professionals worked on this report with the biophysicist Donella Meadows being the principal researcher. The conclusion of the report of 1972 deserves a special mention as it warns that if the growth of the global population, pollution, food production and the exploitation of natural resources is maintained, the world will reach its growth limits over the next one hundred years. In order to make this measurement, the authors conducted computer simulations using the program World3.<sup>16</sup> The conclusion is that on the planet on which we live with limited resources, the dynamics of exponential

growth of the population and GDP per capita are not sustainable (Meadows, 1972). It should be noted that in 2004 the book “Limits to growth: the 30 year update”, was published. This book updated some data and concludes that “there cannot be unlimited population, economic and industrial growth on a planet with limited resources” (Meadows, 2004). Sharing the same line of thought is the not-for-profit organisation Population Matters<sup>17</sup> which promotes the reflection of the consequences of population growth on the environment. In its publications, Population Matters considers that the optimal world population would be between 2.7 and 5.1 billion inhabitants. This figure has already been substantially exceeded as in October 2011 there were 7 billion inhabitants and the population is growing continually.

Although Malthus’ study constitutes a reference text of many studies on the sustainability of population growth, there are others that disagree with this point of view. Authors such as Marx indicate that scientific and technological progress will make the exponential growth of resources possible. The Marxist point of view is that in a human society there is no external law about population and that the existence of a relative overpopulation in a capitalist society is a consequence of the accumulation of capital.

### 3. Population growth

All of the problems that we are analysing are caused by population growth. The real problem would be that the world is heading towards a scenario of continuing population growth which would force us to return to the Malthusian arguments of unsustainability.<sup>18</sup> If we extrapolate the growth rate shown in Graph 3, it is easy to create a scenario of a catastrophic future. However, although extrapolation is a simple exercise, it can also be the wrong method. According to UN data (UNdata, 2012), there are currently twenty births and eight deaths per year for every thousand people.<sup>19</sup> Therefore, the population grew at 12 people per 1000 per year in the five-year period to 2015. A fundamental statistic in order to make predictions is the specific death rate per age. This tells us for each

<sup>17</sup> It was previously known as Optimum Population Trust and its head office is in the United Kingdom.

<sup>18</sup> This does not mean that in the case where the population ceases to grow sustainability is guaranteed, as the real problem is the consumption of resources and this can increase even though population growth is stagnant.

<sup>19</sup> If we were talking about a country, as well as births and deaths we should also take migratory flows into account. However on a global level migratory flows are cancelled out.

<sup>20</sup> It is worth mentioning that before the Industrial Revolution, population growth was moderate and unstable. Therefore we can observe few changes if we begin the graph before 1700, specifically we would observe instability and stagnation in the population prior to this period.

<sup>14</sup> Population bomb.

<sup>15</sup> The Limits to Growth.

<sup>16</sup> The many simulations conducted using the computer program World3 indicate an overshooting in the use of natural resources, which will lead to their exhaustion, and the subsequent collapse of agricultural and industrial production. The final consequence is the sharp decrease in human population.

**Table 1**  
Evolution of the fertility rate in the world.

Year	Total fertility rate
1950–1955	4.95
1955–1960	4.89
1960–1965	4.91
1965–1970	4.85
1970–1975	4.45
1975–1980	3.84
1980–1985	3.59
1985–1990	3.39
1990–1995	3.04
1995–2000	2.79
2000–2005	2.62
2005–2010	2.52
2010–2015	2.36

Source: own elaboration based on UNdata (2012)

age  $N$  the proportion of people that die before turning  $N+1$  years. In [Graph 4](#) we can see the evolution of the population over the last three centuries.

When analysing [Graph 4](#), caution should be taken to note that it does not show us the total population amount but its growth. That is, at no time can we draw the conclusion that the population is decreasing because in this case the curve would have to be located in the negative values of the axis.<sup>21</sup> What we can appreciate is that, if we leave Africa out, there has been a slowdown in the pace of growth. If this trend continues, the population could stabilise which would put an end to several of the potential problems that we are analysing. It is important to highlight that the replacement rate in rich countries is close to 2.1 while in areas where there is a high infant mortality, more than 3 children per woman would be necessary to stabilise the population. In global terms, the generational replacement rate is currently 2.33 children per woman. This rate has decreased substantially in recent years as shown in [Table 1](#).

However, as we know that this fertility rate is heterogeneous in the world, in [Graph 5](#) we can see the distribution of the fertility rate throughout the world. From the graph above we can deduce an inverse relationship between the level of economic development and the fertility rate.<sup>22</sup> In [Graph 6](#) we have placed the HDI on the horizontal axis and the fertility rate on the vertical axis and as a result have obtained that those countries with a higher level of well-being according to the HDI have a higher fertility rate.

With these same data different progressions and prospective estimates have been carried out, including that of Ansgar Seyfferth<sup>24</sup> who indicated the possibility that the global population would peak this century and then begin to decrease. In other words, we are faced with a dilemma with respect to future perspectives. If we consider what has happened until now and extrapolate, we have a scenario with a large population. If we analyse the recent evolution over the last few years, we can see that population growth has slowed down<sup>25</sup> and that, if this trend extends to other countries, we could find ourselves at the upper limit in terms of population levels.

<sup>21</sup> It is therefore a graph that expresses the variation and not the total volume of the population.

<sup>22</sup> In the graph, the situation of France is striking given that it is one of the countries that, having a high level of economic development, also has a high fertility rate. The case of France will be addressed later in the paper.

<sup>24</sup> Director in Spain and Portugal of STAT-UP Statistical Consulting & Data Science.

<sup>25</sup> The slowdown in global terms is due to the drastic slowdown that has been experienced in those countries that have already gone through the demographic transition (with some exceptions such as France).

#### 4. Growth in production

Although we have analysed the predictions for the future evolution of population in the previous point, it is much more complex to make future GDP forecasts. The evolution of the population depends on factors such as the present population or the current age pyramid. However, predicting the GDP of 2050 would be an imaginative task lacking in precision, although we do have forecasts for years such as 2030. In [Table 2](#) we can see the predictions of the evolution of GDP and the population for the coming years.

As we have seen in this article, despite the constant population growth, the GDP per capita is continually growing and it is expected to continue to do so. However, the threat is not so much the fact that the GDP per capita is continually growing, rather the cost that this growth has in terms of the environment. The key lies in productivity and the technological level, given that, if this is not improved, the only way of producing more is with more work, more effort in terms of capital or making a greater use of other resources. The problem of growing without productivity increases or technological improvements is that a use would be made of factors that harm the planet and are maybe limited.

In macroeconomic terms, we can define the function of production as a function that depends on the level of technology and productivity ( $A$ ), the level of capital ( $K$ ), the level of labour ( $L$ ) and other factors. On the other hand,  $\alpha$  indicates how productive the capital is in an economy while  $(1 - \alpha)$  indicates how productive labour is. Therefore, the function of production of a country  $i$  would be:

$$Y = A_i * R_i * K_i^{\alpha} * L_i^{(1-\alpha)}$$

Where  $\alpha$  is a parameter that takes values between (0,1) for each country.

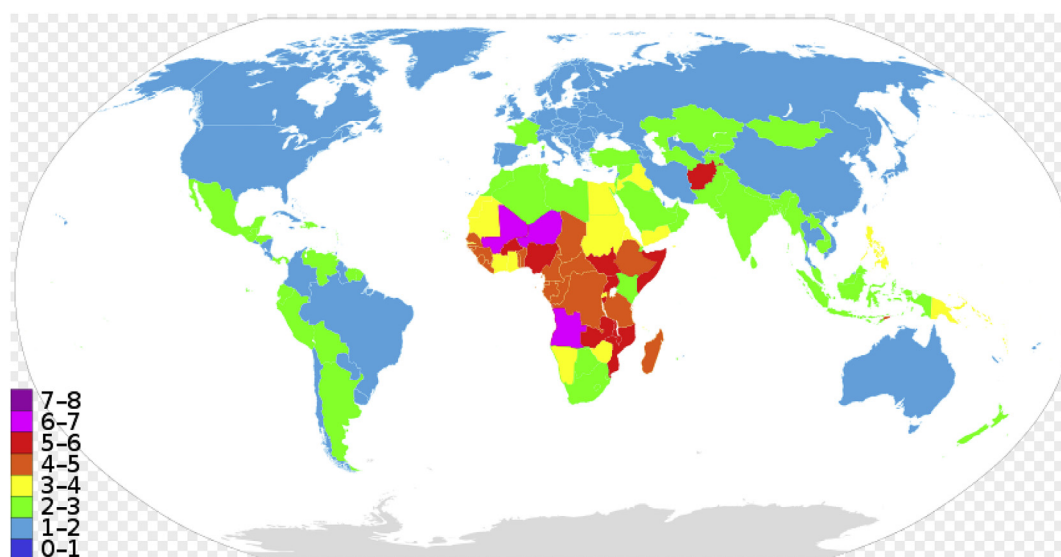
If, in a country  $i$  an increase in production  $\Delta Y$  occurs, this is due to the overall variation of each of the factors of this country, that is,  $\Delta Y = F(\Delta R_i, \Delta A_i, \Delta K_i, \Delta L_i)$ . In the long term, the only factor that breaks the so called Malthusian trap is  $A$ . Only productivity, knowledge, ideas or technology are able to generate continued increases in wealth in a world with limited resources. However, a growth in wealth based on  $R$ ,<sup>26</sup>  $K$  or  $L$  gives rise to greater pressure on the planet given that to achieve this, a greater use of resources such as water, energy and food is required.

The problem of a continued growth in wealth is that in order to avoid generating pressure on the limited resources of the planet it should be largely based on a growth of  $A$ . When a country grows without a growth in  $A$ , the increase in its wealth has a cost for the planet and generates a huge tension on limited resources such as water, energy and food as a large number of reports, books, articles and others show ([Abadía Sánchez, 2011](#); [Aldaya and Llamas, 2012](#); [Allan et al., 2015](#); [Caballer and Guadalajada, 1998](#); [Cabrera et al., 2009](#); [Comunidad de Madrid, 2012](#); [Ederra and Murugarren, 2010](#); [Hoffman, 2004](#); [Hardy et al., 2012](#)). These analysis are related with the consumption of resources, highlighting aspects such as saving water in agriculture, essential to produce food, or in energy production and energy saving within the water sector, which is a great consumer of energy, that is, the inefficient or excessive consumption of resources, or even just one resource, leads to scarcity and pressure on the planet. One way of obtaining a superficial estimate of the incidence of technology and productivity is to analyse the evolution of CO2 emissions. Technological improvement could give rise to an increase in GDP with a reduction in emissions.<sup>27</sup> [Graph 7](#) shows the evolution of the CO2 emissions on a global level.

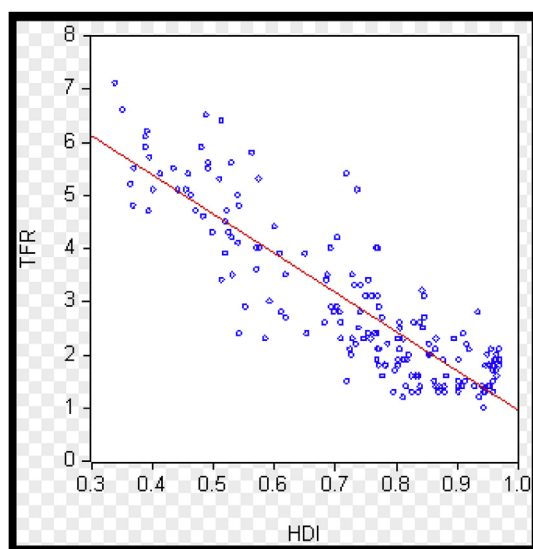
We can observe a more or less continued rate of increase in which we

<sup>26</sup>  $R$  is the “other resources” factor, covering everything that is not technology, labour or capital.

<sup>27</sup> It is worth pointing out that the CO2 emissions are only one indicator of the pressure that economic growth and the population generate on the planet, but there are many others such as the loss of biodiversity, the accumulation of waste, the exhaustion of non-renewable resources.



**Graph 5.** Global female fertility rate in 2016.  
Source: CIA World Factbook (2016).



**Graph 6.** Relationship between HDI<sup>23</sup> and fertility.  
Source: Human Development Report 2009 (United Nations Development Program).

can find small and transitory reductions in emissions in the two oil crises (1973 and 1979) and the recent economic crisis of 2008. However, it is interesting to note that, although the global pace of CO<sub>2</sub> emissions per capita is increasing, this rhythm is not homogeneous across the world, given that those countries experiencing recent development, such as China and India (Graph 8) are those that are strongly increasing their emissions per capita. However, developed countries such as Spain or the USA have reduced their emissions per inhabitant (Graphs 9 and 10).

The large difference between advanced economies and others whose industrial growth is still at a very high level is that a sustainable development that respects the environment is, in the former a fundamental

<sup>23</sup> The HDI is an indicator that takes into account the level of economic development, life expectancy at birth and the level of education.

**Table 2**

Forecasts of GDP and population variation.

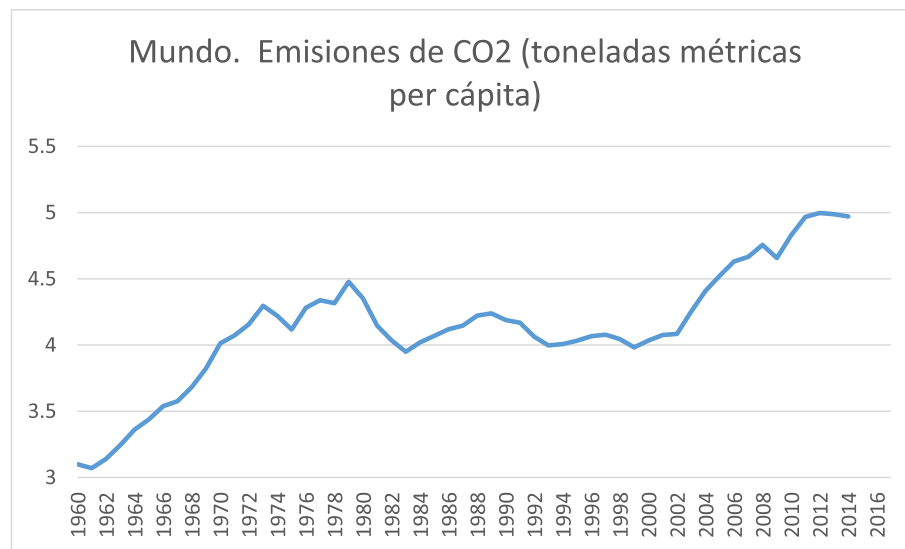
	Distribution of the global population %		Distribution of global GDP %		Increase in GDP	Increase in GDP per capita
	2006	2030	2006	2030		
Western Europe	6	5	18	13	1.9	1.9
USA	5	4	20	17	3.2	1.9
Other western countries	1	1	3	2	3	2
<b>The West</b>	<b>12</b>	<b>10</b>	<b>40</b>	<b>33</b>	<b>2.6</b>	<b>2.2</b>
China	20	18	17	24	7.6	6.4
India	17	17	6	10	10	6.8
Japan	2	1	6	4	0.9	1.4
Other Asian countries	20	22	14	15	5.2	2.8
Latin America	9	9	8	6	2.7	1.3
Russia and Eastern Europe	6	5	6	5	2.3	2.4
Africa	14	18	3	3	3.5	0.7
<b>Rest</b>	<b>88</b>	<b>90</b>	<b>67</b>	<b>67</b>	<b>5.2</b>	<b>3.2</b>
<b>World</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>4.2</b>	<b>2.5</b>

Source: Own elaboration based on the databases of Angus Maddison

issue or, in the latter, an unnecessary luxury.<sup>29</sup> If the emissions per capita are increasing in the world<sup>30</sup> it is because there is a group of economies in which the priority is not to grow with a minimum consumption of the

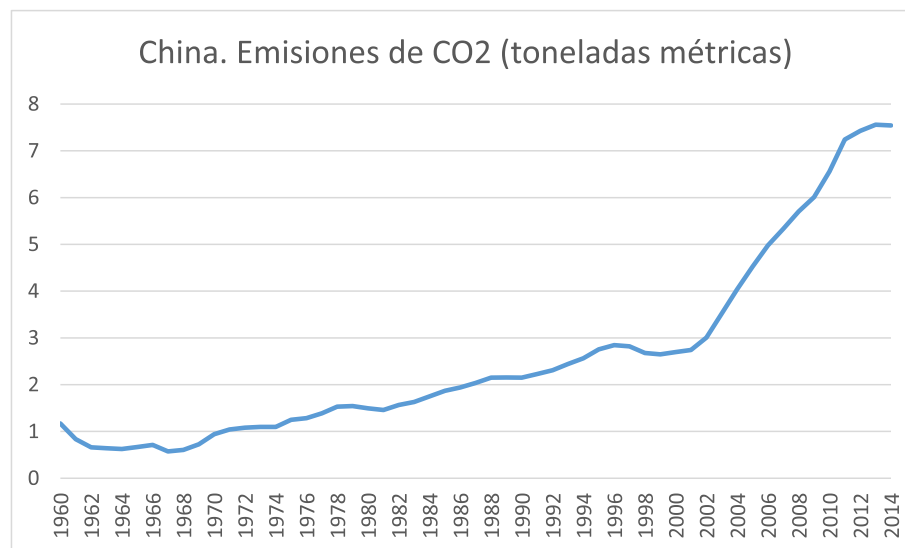
<sup>29</sup> In this sense, in regions such as Europe, there is concern about the environmental effects of economic development which is reflected in more efficient vehicles, water purifying and reuse systems, efficiency in energy uses. However, caring for the environment is costly and is perceived as a luxury for countries with a lower level of development.

<sup>30</sup> It should be noted that the CO<sub>2</sub> emissions are a global problem but there is no clear global action to address this phenomenon. In the same way as the emissions this is the case with many adverse environmental effects, the planet does not have a coordinated global action to address them. Even so, certain regions, such as Europe, occasionally take measures whose effectiveness would require them to be extended to a global level (or at least their greater effectiveness as, evidently, although only certain regions apply the changes, it is better than no region applying them at all).



**Graph 7.** World CO2 emissions.

Source: Own elaboration based on the World Bank data.<sup>28</sup>



**Graph 8.** CO2 emissions per inhabitant in China.

Source: Own elaboration based on the World Bank data.

limited resources but to simply grow as much as possible. It is worth highlighting that the analysis that we have conducted on CO<sub>2</sub> emissions is a mere example, given that we could have measured other indicators of the extent to which growth is accompanied with productivity enhancement, for example, daily energy consumption per inhabitant. Although it is true that a developed economy will have an average energy consumption per inhabitant much higher than a backward economy, the use of more advanced vehicles, more innovative machines and, in short, more efficient technology, can lead to a reduction in the energy consumption per person without a reduction in wealth (CEC (California Energy Comisión), 2005). This type of growth, which is more efficient in

the use of resources, is the only one capable of enabling a continued growth of GDP per capita in the long term. However, a growth model such as the current model in China<sup>31</sup> is completely unsustainable as its growth requires an excessive and increasing use of the limited resources available on the planet.

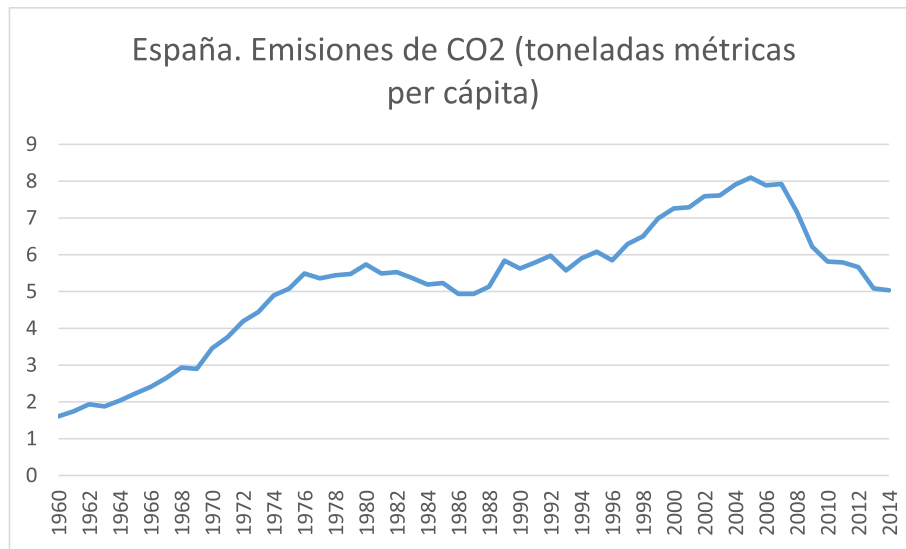
## 5. The end of the long-term correlation between economic and demographic growth

The problem we are faced with in the long term is the challenge that technology will have, given that technical progress should enable economic growth that does not use higher quantities of physical resources. However, everything seems to indicate that population growth will slow down either because it will gradually decelerate until a point when it starts to decrease or because it will drop drastically due to an unfortunate event such as a war or catastrophe. Due to this uncertainty, we are going to put forward three possible scenarios of what we can expect over the coming decades:

<sup>28</sup> They can be downloaded at <https://datos.bancomundial.org/indicador/EN.ATM.CO2E.PC?end=2014&start=1960&view=chart>.

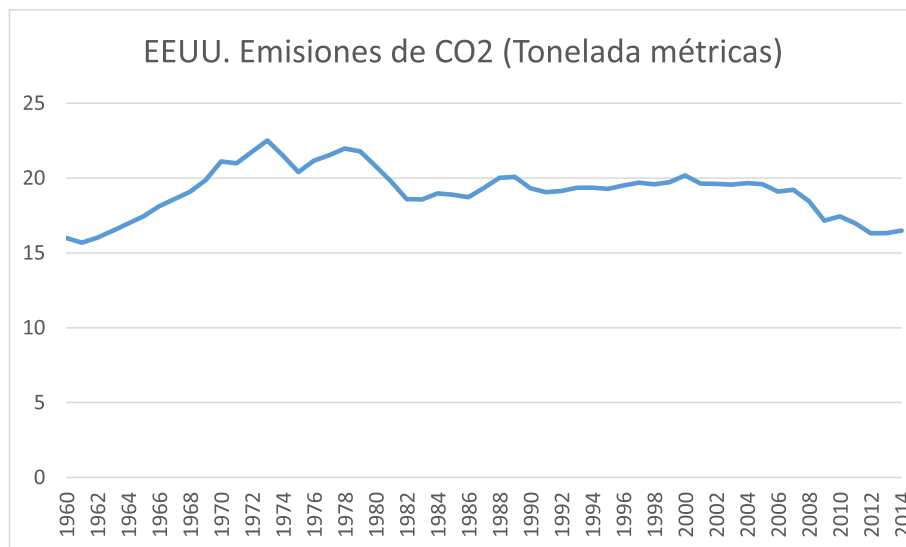
<sup>31</sup> The problem with China is not so much the level but the trend. But if we analyse the current volume of emissions, the USA has a much more polluting development than China.





**Graph 9.** CO2 emissions per inhabitant in Spain.

Source: Own elaboration based on the World Bank data.



**Graph 10.** CO2 emissions per inhabitant in the USA

Source: Own elaboration based on the World Bank data.

-Scenario 1: The population will continue to grow for a limited length of time which could last until the end of the century. Technology will be able to partly bear the population growth rate so that the consequences for the planet will be bearable in the long term.

-Scenario 2: The population will continue to grow for an unlimited length of time, but, technological progress will not be able to maintain the level of wealth per person without generating an enormous impairment to the physical resources of the planet leading to serious consequences for the planet and all of its inhabitants.<sup>32</sup>

-Scenario 3: An event will drastically diminish the resources available on the planet before demographic growth changes its trend.

Making a long-term forecast in which the population continues to grow is somewhat simplistic, since is based solely on prolonging the series of the evolution of the population which to date has been exponential since the beginning of the industrial revolution. However, if we break down the world population into countries, we will see that a demographic transition has occurred in many of them. In particular, countries in a phase preceding the demographic transition show higher population growth rates when their GDP per capita increases, but this relationship between the growth of wealth and that of the population disappears when the country has gone through its demographic transition.

On a global level, if we take all of the available data,<sup>33</sup> we can observe

<sup>32</sup> To some extent, the difference between the first two scenarios is theoretical, given that if there was a debate between experts there would be those who would defend that the economic development that has taken place up to now has generated irreversible environmental effects and those who would defend the opposite argument.

<sup>33</sup> The data series begins in year zero, however, for each country there is a different amount of data. Fundamentally, the larger differences with respect to the sample size are in the very old data, as some countries have a greater availability of data than others.

**Table 3**  
Prediction model of the population between years 1–2016<sup>35</sup>.

Dependent variable	TVPworld	TVPOPUSA	TVPOPChina	TVPOPGermany	TVPOPUnitedKingdom	TVPOPAustralia
Constant	0.57**	0.06	0.11	0.21***	0.32***	0.4***
TVGDPI	0.30***	-0.001	0.03***	0.05***	0.02	0.01
TVPOP-1	0.21***	0.96***	0.83***	0.38***	0.39***	0.82***
R2	0.63	0.93	0.69	0.36	0.15	0.68
P-Value (F)	0.00	0.00	0.00	0.00	0.00	0.00
Dependent variable	TVPVietnam	TVPSpain	TVPFrance	TVPMexico	TVPSouthAfrica	TVPArgentina
Constant	0.3***	-1.83*	-0.01	-0.00	0.03	0.00
TVGDPworld	-0.01	1.66***	1.12***	0.55***	1.79***	0.78***
TVPOP-1	0.87***	0.00	0.14**	0.61***	0.02	0.39***
R2	0.88	0.84	0.37	0.69	0.84	0.56
P-Value (F)	0.00	0.00	0.00	0.00	0.00	0.00

Source: own elaboration. The data have been obtained from the database of Angus Maddison

**Table 4**  
Prediction model of the population with the data of the last 50 years, between the years 1967 and 2016<sup>36</sup> (both included).

Dependent variable	TVPworld	TVPOPUSA	TVPOPChina	TVPOPGermany	TVPOPUnitedKingdom	TVPOPAustralia
Constant	0.69**	0.52***	0.58***	0.00	0.01	0.25*
TVGDPI	0.00	0.00	-0.04***	0.01	0.01	0.02
TVPOP-1	0.53***	0.49***	0.70***	0.90***	0.94***	0.79***
R2	0.42	0.42	0.64	0.74	0.85	0.62
P-Value (F)	0.00	0.00	0.00	0.00	0.00	0.00
Dependent variable	TVPVietnam	TVPSpain	TVPFrance	TVPMexico	TVPSouthAfrica	TVPArgentina
Constant	1.93***	0.19*	0.00***	0.00***	0.00***	0.00***
TVGDPI <sup>a</sup>	-0.00***	-4.63	0.03***	0.02	0.02	0.00
TVPOP-1	0.25***	0.87***	0.50***	0.73***	0.73***	0.66***
R2	0.80	0.77	0.43	0.62	0.62	0.61
P-Value (F)	0.00	0.00	0.00	0.00	0.00	0.00

<sup>a</sup> The “i” refers to the country in question, given that each model is constructed with data from each country.

Source: own elaboration. The data have been obtained from the database of Angus Maddison

that the greater the increase in wealth the greater the increase in the population, but when we take just the last 50 years, the wealth per capita does not significantly explain the evolution of the population. When the same model is applied to the last fifty years, the world GDP per capita has already become separated from the evolution of the population. Therefore, if we estimate the model country by country we will find significant differences depending on whether it is a developed country or not. The model that we are going to calculate follows the following theoretical equation:

<sup>34</sup> There are two fundamental reasons for deciding to estimate the model for the last fifty years: First, if we take all the data for industrialised countries, the model will also use those periods in which the country was experiencing its demographic transition which is precisely a period of high growth of GDP per capita accompanied by high population growth. - Second, if we extend the model to more than the last fifty years, we will be considering the period of the recovery from the Second World War which, in many countries, implied a high growth rate of GDP per capita together with a high population growth.

<sup>35</sup> In our sample we have data from year 1–2016. However, each country has an amount of years with data. In order to elaborate the models we have taken from each country only those years for which there is data of both the GDP per capita and the population. The same years have not been taken for all countries given that they have been selected based on the available data in each country.

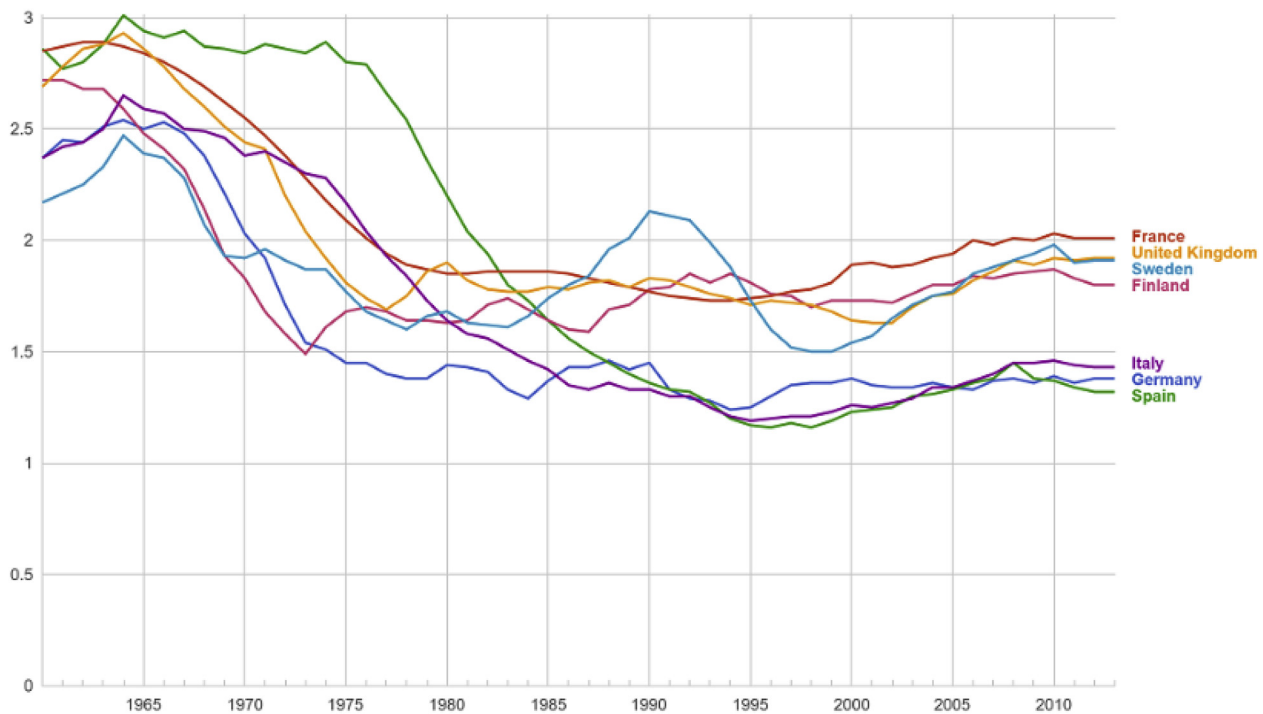
<sup>36</sup> We have taken 50 years in order to have a rounded and aesthetic figure and also to temporarily remove ourselves from a period too close to the Second World War. However, something to take into account in the period considered is that it includes the recession of 2008. During this crisis, countries such as Spain experienced a demographic decrease in the number of births together with a decrease in income. Therefore, the links between GDP per capita and the variation rate of the population appear even stronger in the models than they are in reality due to the influence of this short-term cycle. The above-mentioned point gives even more credibility to the result that there is no significant relationship between wealth and the evolution of the population given that the joint reaction of the demography and economy during the crisis of 2008 could make the coefficient  $\beta_1$  of the different models seem significant.

$$TVpoblación = \beta_0 + \beta_1 * TVGDPpc + \beta_2 * TVPOP_{t-1} + u$$

The hypothesis that we propose a priori is that the coefficient of  $\beta_1$  will not be significant in developed countries and will be in developing countries when the model is applied for the last fifty years.<sup>34</sup> This equation has been estimated using ordinary least squares using the available information from “The Maddison Project Database”, which provides information on comparative economic growth and income levels over time. The result can be consulted in [Tables 3 and 4](#).

A priori, our hypothesis was that, if we took countries such as China or Vietnam we would observe that as the GDP per capita grew so would the population, but the growth in income per capita would no longer be a significant variable in developed countries. In the estimate obtained for the entire period in most countries there is a close relationship between GDP and population growth, however, there are exceptions where it would be appropriate to conduct a deeper analysis. The results obtained show that countries such as Spain, France or South Africa see a significant part of their population explained over time as a result of economic conditions, which shows their high coefficient of the GDP per capita variable. In addition, in other countries this relationship is also significant, but to a lesser extent, which shows the complexity of the demographic evolution analysis. On the other hand, in the estimate for the last 50 years there are few significant coefficients for the GDP variable, thus confirming that the relationship between population and economic conditions is altered when the demographic transition has passed. However, this does not mean that the relationship is over but, as countries evolve and become more complex, the interrelationships within their socio-economic systems become more difficult to identify, analysis that would require very specific information from each country. Finally, China and Vietnam show negative coefficients, a result without doubt striking that could indicate that the relationship between GDP and population growth is not constant throughout the demographic evolution of each country.

One of the few exceptions that we can find is France. This is since in



**Graph 11.** The evolution of the birth rate.

Source: Eurostat.

this country the birth rate is one of the highest in Europe, being the only country with a rate above 2% as [Graph 11](#) shows, so France has the highest evolution of the birth rate among several European countries. This is precisely one of the causes why the rate of change of the population in France is correlated (which does not mean that it is a cause) by the rate of variation of GDP per capita. If we look for the causes we should point out that France was one of the first countries to approve policies to help families and, at the same time, policies have not been implemented to penalise single parents. In the case of France, almost 4% of GDP is dedicated to supporting families; childcare facilities (used by almost 40%) are free in 92% of cases. Furthermore, 18% of the budget for families is dedicated to childcare: the subsidies per child exceed 900 euros and parents are entitled to 16 weeks leave, which increases to 26 if it is a third child (that is, the subsidies increase when the number of children is higher).

We can see that the interaction between the growth in wealth and that of the population seems to disappear when the country has reached a high level of development.<sup>37</sup> In this way, there are countries whose population will increase as their GDP per capita increases and there are others which have decoupled the evolution of their population from the variation in income in long-term cycles. Although we have found that developed countries have separated their demography from their economy in the long term, they are susceptible to drastic and sudden changes in the economic cycle. In [Graph 11](#) we can see how, during the growth cycle between 1979 and 1999, in Spain<sup>38</sup> the number of births had been decreasing. Then between the year 2000 and the beginning of the crisis in

2008 there was an increase in the number of births. Therefore, if we take the period between 1979 and 2008, the evolution of the number of births does not seem to be related to the change in GDP per capita, but the aggressive short-term variations such as the crisis of 2008 do seem to produce an evident change in the evolution of the number of births as shown in [Graph 12](#).

In conclusion, we can see that once countries have reached certain level of economic development, they do not seem to respond to the evolution of their wealth with their demographic evolution<sup>49</sup>. This is an interesting nuance which, in the long term, distances us from the scenarios of an unlimited growth of the world population. However, in many areas of the world where economic development is still low, a relationship between the evolution of the economy and demographic growth can be observed. The definitive question for a prosperous future on the planet is that as well as achieving a stabilisation of population growth in the long term we should also stabilise the consumption of resources, particularly when this consumption is not renewable or has harmful effects for the planet.

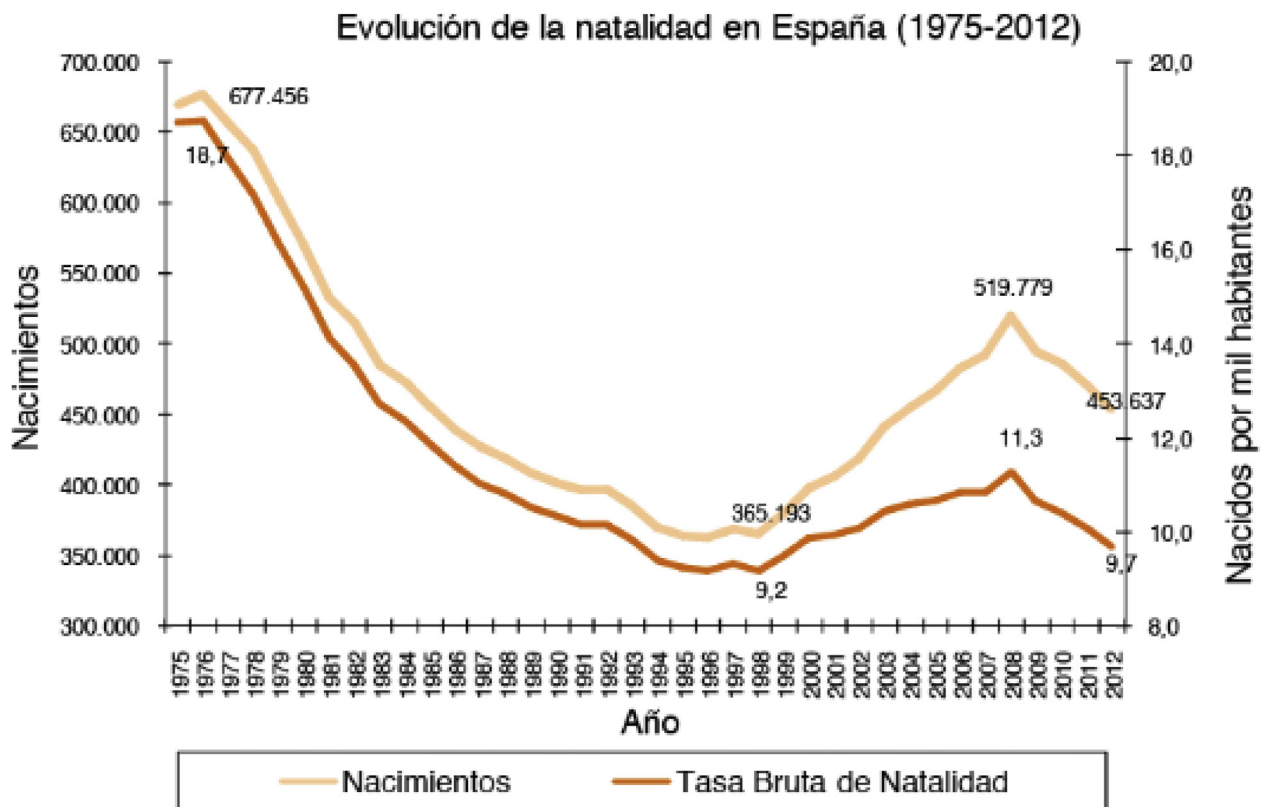
## 6. Conclusions

As we have analysed, population growth is the key element when understanding the future pressures on basic resources for production and on the deterioration of the environment. On the other hand, technology and productivity constitute a key piece as they are the only possible means to increase production given the same level of resources used. We began our analysis by remembering Malthusian theory as, although during the last few centuries technology has been able to generate an increase in GDP per capita despite the huge increase in world population, a collapse in one of the fundamental resources could give rise to a future not far removed from the theory described by Malthus.

<sup>37</sup> This is one of the fundamental pillars on which the assumption that the long-term growth of the population will end is based, given that as countries become more developed their demographic growth diminishes. On the other hand, a continued demographic growth in a country that has not developed economically would be unsustainable due to the lack of resources, giving rise, in this case, to the situation described by the Malthusian trap.

<sup>38</sup> If we take another developed country instead of Spain, we will obtain very similar results in the evolution of its birth rate during the period of the 2008 crisis.

<sup>49</sup> Except in aggressive short-term changes, such as the crisis of 2008. In other words, the demographic evolution does not respond to the long-term growth in wealth but it can respond to short cycles due to small crises or occasional phases of expansion.



**Graph 12.** The evolution of the number of births.  
Source: Statistics National Institute (Spain).

Many of the problems of pollution, the deterioration of the environment and the scarcity of products have been analysed from different disciplines, but all these problems in reality represent a series of symptoms of the real problem; population growth. We have seen that, although the growth rate has been exponential, there is evidence to suggest that it is slowing down. Countries with a higher index of human development have a lower birth rate and on the other hand, the world's average fertility rate has fallen from 4.95 in 1950–1955 to 2.36 in 2010–2015. At the same time, an increase in the level of production has also been observed which has been partly based on technological progress, the increase in labour, the higher capital investment and the increased use of resources. Based on this greater use of factors of production, future scenarios can be predicted of tension between the demand and supply of certain resources. Therefore, in future articles we will seek to address the specific case of three markets of factors of production and consumption that are fundamental for humans: water, energy and food.

We also have confirmed that one of the Malthusian theories is no longer operative in all countries. A growth in wealth per capita no longer necessarily implies a growth in the population. We have constructed a model that explains population growth depending on its trend and the rate of change of GDP and we can observe that there are two types of country. First, there are the developed or post demographic transition countries. In these countries a long-term variation in wealth does not affect the level of the population, although a short-term GDP shock would affect it. The confirmation of this duality of countries is a fundamental issue related with all the problems mentioned. It should not be forgotten that sustainability is a very complex issue linked to society as a whole, which converts elements as pollution, state of the environment, availability of resources, productivity, technical and technological progress, efficiency and demographic evolution in key aspects. For this reason, this

is an essential investigation, since it will address all these aspects by analysing its role on sustainability, making this article the basis that will allow the research to continue and make predictions as accurately as possible. However, this article is just the start of a bigger research, so it leaves aside fundamental issues related with food, water and energy that will be investigated in future articles. In addition, a greater number of countries and variables related to the demography and economy of a country should be considered with the aim of conducting a more in-depth analysis of the relationships between the various factors of interest and the growth of the population.

#### Declaration of competing interest

There is no conflict of interests.

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